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Physicochemical, functional and sensory properties of wheat noodles substituted by sorghum and mung bean flours

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Abstract

Noodles are flour-based processed products that are generally served as an alternative food to carbohydrates dense products. Nowadays, carbohydrate-based processed products, such as the production of non-wheat noodles and the substitution of non-wheat carbohydrate sources, are developed, mainly through the use of local food commodities as alternatives. The purpose of this research was to investigate the physicochemical qualities of wheat noodles substituted for local food ingredients such as sorghum flour and green beans via sticking properties, cooking quality, proximate analysis, and sensory characteristics. Resistant starch and dietary fibre content were the functional features studied. Five formulas were established, each with a different amount of wheat flour, sorghum flour and mung bean flour used in the processing, namely N1 (50:20:30), N2 (40:30:30), N3 (30:40:30), N4 (20:50:30), and N5 (10:60:30). The peak viscosity of the five composite flour formulae was 1421-1778, the breakdown value was 454-535, and the ultimate viscosity was 1967-2490, with a cooking loss of 10.69-23.21%. According to proximate analysis, the formulated noodles provide complete nutritional content to meet nutritional adequacy, namely 375-381 kcal/100 g. It not only has a great nutritional value, but it also has strong physiological advantages for the body due to the high concentration of dietary fibre (9.6-9.8%) and resistant starch (14.93-15.01%). The taste, texture, and aroma of the sample formulae N2, N3, and N5 are comparable to wheat-based noodles. The five wheat noodles substituted by sorghum and mung bean flour formulations were potentially developed into functional products with comprehensive nutritional content, high dietary fibre, and resistant starch. Further research is needed to confirm its functional properties on health.

1. Introduction

Nowadays, dry noodles or instant noodles are fast becoming an alternative staple food consumed by modern civilization. This product is in great demand because it is easy to obtain at a low price, practical, quickly served, and has good taste. The previous study proved that noodle consumption was increasing in China (41,450 million), Indonesia (12,520 million), India (6,730 million), Japan (5,630 million), and Vietnam (5,430 million) (WINA, 2020). Noodles are products made from wheat flour, rice flour, or other flour as the major elements, with or without other ingredients, using a pre-gelatinization and dehydration process either by frying or other processes (FAO, 2006). In general, wheat flour is used for the production of noodles all over the world. Meanwhile, wheat flour is produced only in some countries. Several nations are reported to be the top flour users, with percentages ranging from 40 to 50%. As an instant noodle producer, Indonesia continues to rely on wheat imports to fulfil the raw material supply for flour manufacturing.

As a way of an effort to minimize wheat flour imports, research on producing noodles with non-wheat flour is now being conducted. Wahjuningsih *et al*. (2020) developed a noodle product containing sorghum flour, sago, and mung beans with sensory properties similar to wheat noodles. Abidin *et al*. (2013) developed noodles using cassava flour with 80% of the same properties as wheat noodles. The progression of noodle product innovations is varied. It is possible to change 100%

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wheat or use the wheat substitution method. Because wheat protein contributes to forming the protein matrix, it is challenging to substitute wheat as an ingredient in noodles production entirely. Gluten is an appropriate formulation for noodles, which was found on wheat, potato starch, jabuticaba skin, and oysters (Garcia *et al*., 2016; Fen *et al*., 2017; Wahyono *et al*., 2018). Compared to noodles made from wheat flour, noodle innovation with non-wheat flour is intended to enhance the nutritional and functional value of the product. Mung bean flour has similar characteristics flour with wheat flour.

Mung bean is a commercial food ingredient that is frequently utilized in a variety of processed food items. Mung beans contain various compounds involved in phenolic acids, including ferulic acid, caffeic acid, chlorogenic acid, syringic acid, p-coumaric acid, and gentisic acid. Those compounds proved beneficial effects on hypoglycemic, hypolipidemic, anti-hypertensive, and anti-cancer properties (Hou *et al*., 2019). Furthermore, phenolic acids, flavonoids (3 deoxyanthocyanidin), and tannin condensates have some functions as antioxidants, anti-inflammatory agents, anti-diabetic agents, and obesity preventers (Awika, 2017; Xiong *et al*., 2019).

Sorghum has also been developed as a raw material for food development products. Wahjuningsih *et al*. (2020) used sorghum flour for noodle production and showed resistant starch and dietary fibre with 9.63% and 16.35% DB, respectively (Wahjuningsih *et al*., 2020). As the primary component in noodles, Sorghum flour has the potential to provide noodle products with high nutritional value and health benefits. This study aimed to obtain a substitute formula for sorghum and mung bean flour with the best noodle characteristics.

2. Materials and methods

2.1 Materials

The main ingredients used were 60 mesh Cakra Kembar wheat flour, sorghum flour, and mung bean. Sorghum flour is used from Bogor, Indonesia and the mung bean flour is obtained from a local farmer in Semarang, Indonesia. The chemicals used for the analysis were HCl, NaOH, ether, amylase, amyloglucosidase, pepsin, pancreatin, phosphate buffer, n-hexane, and boric acid obtained from Sigma-Aldrich, Co. (USA). The tools used include extruder, cabinet drier, steamer, texture analyzer, oven, desiccator, soxhlet, spectrophotometer and glassware.

2.2 Noodle preparation

The noodle-making method refers to the research conducted by Wahjuningsih *et al*. (2020) with minor modifications. The noodle formula was created by combining five different recipes with varying amounts of three flours: wheat flour, sorghum flour, and mung bean flour (Table 1). Each ingredient was weighed according to the dose and added 30% water. Pre-gelatinization of the dough was done by steaming for 35 mins and left at room temperature. The dough was formed using an extruder and dried at 50°C for 17 hrs. The dried noodles were packaged using polyethylene (PE) plastic and stored for analysis.

Table 1. Noodle formula based on wheat, sorghum and mung bean flours

Formula Code	Wheat (%)	Sorghum (%)	Mung bean (%)
N1	50	20	30
N2	40	30	30
N3	30	40	30
N4	20	50	30
N5	10	60	30

2.3 Pasting properties and cooking quality

The pasting properties of noodles were determined using a Rapid Visco Analyzer (RVA) (Wahjuningsih *et al*., 2020). Cooking loss value was measured by weight reduction between before and after cooking, and a texture analyser determined noodle texture. Both of them were cooking quality assessments (Wahjuningsih *et al*., 2020).

2.4 Proximate analysis

Water, ash, protein, and fat contents of noodle samples were analyzed referred to AOAC (2016). Carbohydrates were calculated using the following formula:

Carbohydrate (%) = 100%-[Moisture (%) + protein (%) + fat (%) + Ash (%)]

2.5 Analysis of starch content and resistant starch

Starch content analysis was determined using the Direct Acid Hydrolysis method (Pirt and Whelan, 1951). The sample (2 g) was weighed and dissolved in 50 mL of distilled water, stirred for 1 hr, and then filtered. The residue was washed with ether to remove fat and continued with 10% alcohol to release dissolved carbohydrates. Then, 20 mL of 25% HCl was added to the residue, covered with a reverse cooler, and boiled for 2.5 hrs. The process was continued by neutralization with 45% NaOH after cooling, adjusted to 500 mL, and filtered. The starch content was calculated after the glucose filtrate value was multiplied by 0.9. The determination of resistant starch was conducted by amylase, amyloglucosidase, and proteases enzymes activities (Wahyuningsih *et al*., 2020).

2.6 Analysis of dietary fibre

Multi-enzyme analysis of dietary fibre content refers to enzymatic activities assay, including amylase, pepsin, and pancreatic activities (Asp *et al*., 1983). One g of noodle samples were homogenated with phosphate buffer pH 6.0, incubated with amylase at 80°C for 15 mins. The second incubation used the enzyme pepsin in buffer pH 1.5 HCl-containing at 40°C for 60 mins. Subsequently, it was incubated using pancreatin at 40°C for 60 mins with a buffer pH of 6.8. The mixture was filtered through a porosity crucible 2 with the addition of 0.5 g of celite. The residue is in the form of insoluble fibre which was reduced by the weight of the residual ash. The filtrate was used to determine the soluble fibre (Asp *et al*., 1983).

2.7 Sensory analysis

Sensory evaluation of multiple comparison tests was carried out on the parameters of taste, aroma and texture. The samples was analyzed using a rating scale +3 = Very More Tasty, +2 = More Tasty, +1 = Slightly More Tasty, 0 = Same as Wheat Noodles, -1 = Slightly Less Tasty, -2 = Less Tasty, - 3 = Very Unpleasant. The sample was presented to 25 panellists at the food sensory lab of the Universitas Semarang. (Wahjuningsih *et al*., 2020). The experimental design of sensory test conforms to ethical principles approved by Dr. Moewardi General Hospital Clinical Ethics Committee No. 1.244/XI/HREC/2020.

2.8 Data analysis

The data was presented in the mean of triplicates data. The data was analysed using SPSS 23.0 by one-way ANOVA. The significant value was tested by Duncan's Multiple Range Test (DMRT) with $p < 0.05$.

3. Results and discussion

3.1 Physical properties

The profile of starchy pasta, including physical and food quality, was an essential standard of product quality in the industrial area (Collado and Corke, 2016). The finding showed that different flour formulas generated distinct pasta characteristics (Table 2). The pasting temperature in various formulas of noodles showed relatively similar to each other, around 82°C. The N3 and N4 performed high peak viscosity in 1770 and 1778, while N1 showed the lowest peak viscosity in 1421. Paste temperature was measured when the viscosity initiated to rise, demonstrating starch capability (Adekoyeni *et al*., 2018). The maximum viscosity is reached by gelatinization of starch, showing the capacity to bind water (Emire *et al*., 2006). The greater the sorghum flour formula, the higher the noodle formula's peak viscosity value (Table 2). A lower number implies an insufficient level of development ability (Marta and Tensiska, 2017). Breakdown viscosity is a measure of how easily cooked starch disintegrates. The N3 noodle composite flour had the most tremendous breakdown value in this research, which might be ascribed to its lower resistance to heating and stirring. The final viscosity of starch is a metric that shows its capacity to form a gel after cooking (Niba *et al*., 2001). The ultimate viscosity of N1 noodle composite flour was lower than that of the other formulae (Table 2). The five noodle samples were chosen based on the cooking quality characteristics. The five noodle samples exhibited cooking losses and textures ranging from 10.69 - 23.21% and 1.26 - 4.27 gf, respectively.

3.2 Chemical composition

Noodle products have thrived in various nations, functioning as a nutritional source of carbohydrate alternatives that are nutritious and easy to prepare, and have become most people's favorites. The National Standardization Body SNI 3551:2012 governs the Noodles level of quality (BSN, 2020). The current study revealed that five formulas of noodles performed nutritional quality standards of 3.79 - 5.40% water content, 1.16 - 1.43% of ash, 11.87 - 14.56% of protein, and 0.25 - 1.16% of fat 79.34 - 82.14% of carbohydrate (Table 3). Formula N3 contains significantly higher protein and fat than other formulas but has significantly lower carbohydrate content. Water content has an impact on product shelf life, which is essential to notice since excessive water availability might encourage the growth of harmful microorganisms (Agustiari *et al*., 2018).

The protein content of sorghum flour was identified at 8.89% db, however, it is complemented by the high

Table 2. The pasting properties and cooking quality of noodle's formula

Sample	Pasting Temperature (°C)	Pasting Properties (RVU)			Peak Time (Min)	Cooking loss (%)	Noodle Texture (gf)
		Peak Viscosity	Breakdown	Final Viscosity			
N1	82.30	1421	454	1967.00	5.60	10.69	3.515
N2	82.25	1623	486	2271.00	5.53	17.35	4.273
N3	82.35	1770	535	2447.00	5.60	13.90	2.997
N4	82.20	1778	440	2490.00	5.53	16.51	3.342
N5	82.25	1503	306	2416.00	5.33	23.21	1.262

Values are presented as means of triplicates. N1 = 50% wheat:20% sorghum, N2 = 40% wheat:30% sorghum, N3 = 30% wheat:40% sorghum, N4 = 20% wheat:50% sorghum, N5 = 10% wheat:60% sorghum.

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Table 3. Chemical composition of wheat noodles substituted by sorghum and mung bean flours

Composition	N1	N2	N3	N4	N5
Water Content (%)	3.79±0.06^{a}	3.88±0.06^{a}	4.60±0.09^{c}	4.08±0.07^{b}	5.40±0.08^{d}
Ash Content (%)	1.43±0.01^{d}	1.30±0.01^{b}	1.29±0.01^{b}	1.32±0.01^{c}	1.16±0.01^{a}
Protein Content (%)	12.1±0.03^{a}	13.99±0.10^{b}	14.56±0.36^{c}	13.79±0.21^{b}	11.87±0.04^{a}
Fat Content (%)	0.32±0.01^{e}	0.31±0.00^{d}	1.16±0.01^{a}	0.23±0.00^{b}	0.25±0.01^{c}
Carbohydrate Content (%)	82.14±0.08^{d}	80.53±0.04^{b}	79.34±0.47^{a}	80.58±0.27^{b}	81.32±0.04^{c}
Total Energy (kcal/100 g)	381±0.29^{d}	381±0.23^{d}	377±0.39^{b}	380±0.23^{c}	375±0.40^{a}
Energy from Fat (kcal/100 g)	2.92±0.06^{e}	2.79±0.00^{d}	1.48±0.06^{a}	2.07±0.00^{b}	2.23±0.06^{c}
Starch Content (%)	57.74±0.10^{a}	59.40±0.05^{b}	61.87±0.10^{d}	60.08±0.16^{c}	60.34±0.10^{c}
Amylose (%)	24.64±0.08^{b}	24.12±0.17^{a}	23.98±0.08^{a}	24.59±0.09^{b}	24.13±0.00^{a}
Amylopectin (%)	33.10±0.01^{a}	35.28±0.22^{b}	37.89±0.01^{e}	35.49±0.07^{c}	36.21±0.10^{d}

Values are presented as mean±SD. Values with different superscript within the same row are significantly different ($p < 0.05$).

protein content of wheat and mung beans (19.07% and 22.89% db, respectively) (Wahjuningsih *et al.*, 2020). Protein is essential in the preparation of noodle dough. Wheat flour protein is responsible for the formation of continuous dough and noodle strands. Protein absorbs water and creates a restricted network of gluten during the dough-making process. Furthermore, it is a significant influence on the quality of noodles (Baik, 2010). Noodles are energy-dense food components since they are the primary source of carbohydrates other than rice.

This wheat noodles formula with sorghum and mung bean flour substitute has a total energy of 375 - 381 kcal/100 g and low-fat energy of 1.48 - 2.92 kcal/100 g. This low-fat level is also appropriate for customers who demand a low-fat diet. The starch content affects the texture of the noodles as well. The starch granules absorb water and gelatinize throughout the cooking process, resulting in soft, cooked noodles. Starch is composed of two distinct molecules: amylose and amylopectin. The variation in the content of the two molecules will also impact the properties of the noodles, such as their capacity to absorb water, gelatinize, and retrograde (Baik, 2010). The high amylose caused the noodle texture to be stiffer, while low amylose caused cooking times faster, and the texture will be soft. This characteristic is essential for producing noodles with the same gluten content as flour-based noodles (Pa).

3.3 Sensory profile

Figure 1 illustrates the importance of sensory qualities of noodles based on flavour, aroma, and texture. In comparison, N3 and N5 exhibited flavour qualities similar to non-substituted wheat noodles (Figure 1a). Formula N5 has nearly the same textural qualities as wheat noodles (Figure 1c). Compared to N1 and N4, the aroma of N5 is virtually identical to that of wheat noodles. The sample code N5 (wheat flour 10%, sorghum flour 60% and mung bean flour 30%) has a greater amylopectin concentration than other formulations, it can be performing firm, smooth texture, high elasticity, and wheat noodles characteristics (Li *et al.*, 2017).

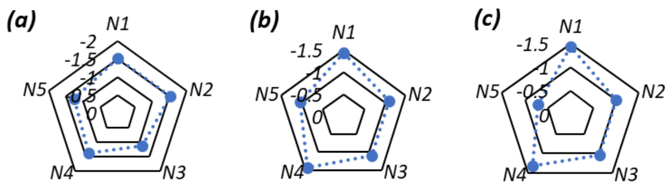

Figure 1. Sensory Value of Multiple Comparison Test Method; (a) taste, (b) aroma and (c) texture of wheat noodles formula with sorghum and mung bean flour substitution.

3.4 Functional properties

The rise of degenerative illnesses, unhealthy lifestyles, a lack of physical exercise, and excessive intake of foods heavy in fat and sugar are all current polemics confronting society today. In response to rising customer demand, the development of healthy food items has become increasingly diversified. The communities recognize that the value of food intake should be nutritional and provide more advantages to overall health. The primary components in this study were wheat flour, sorghum, and mung beans. Wheat has good dough properties due to its gluten network. Furthermore, it has high nutritional value, but it is hazardous since the allergen component, gluten, is harmful to gluten intolerance. Substitution of non-wheat parts, such as sorghum and mung beans, is one method of reducing wheat usage while simultaneously increasing the diversity of non-gluten-based food ingredients with high functional properties of the product.

Wheat noodles substituted with sorghum flour and mung bean had a total dietary fibre content ranging from 5.86 to 9.80%, according to the findings (Figure 2a). The plant's edible portion or a carbohydrate equivalent is resistant to digestion and absorption in the human small intestine. It is subsequently fermented in all or part of the large intestine (Dhingra *et al*., 2012). Furthermore, carbohydrate was digested by the microbiota in the large intestine to create short-chain fatty acids that are advantageous to health, such as butyrate and propionate. Consumption of dietary fibre helps to improve gut health and blood sugar management (Li and Komarek, 2017). Formulation of N1 and N5 have higher dietary fibre content, there were 9.8% and 9.74%, respectively. Adding more wheat flour and sorghum in more enormous proportions might result in noodles with a high total dietary fibre level. Wheat has a lower total dietary fibre level of 8.69% db than sorghum, which has a higher amount of 10.37% db (Wahjuningsih *et al*., 2020).

The resistant starch content of the N1-N5 noodle formula is illustrated in Figure 2b. The N4 and N5 formulations had more resistant starch than the other formula. The 50-60% replacement of sorghum flour enhanced the production of resistant starch. This resistant starch developed naturally in food commodities, but it can also arise due to processing. Filament processing promoted the production of resistant starch (Kim *et al*., 2006). The development of type 3 resistant starch is induced by the retrogradation of gelatinized starch (Sharma *et al*., 2016)., The gelatinized dough is chilled at room temperature to aid the retrogradation process. Resistant starch, which has characteristics comparable to soluble dietary fibre, is crucial for enhancing intestinal health, regulating blood glucose, and lowering the risk of obesity (Birt *et al*., 2013; Wahjuningsih *et al*., 2018).

4. Conclusion

Noodles are a carbohydrate-rich alternative wheat-based dietary component. Wheat has become the primary ingredient in rice production globally, although its availability is limited, particularly in non-wheat-producing nations. The use of local resources is still undergoing to generate culinary advances. Wheat contains gluten, which may produce an elastic and rough noodle texture. Thus completely replacing it for creating noodles is difficult. Therefore, the substitution of making wheat noodles with sorghum flour and mung beans can produce noodles with nutritional, physical, and sensory characteristics that can be an alternative food for the community itself. Wheat noodles substituted by sorghum and mung bean flour of N3 showed better nutritional value, with protein content 14.56% and fat content 1.16%, higher than the other four formulas. The N3 formula has calories of 377 kcal/100 g. While the formulas N4 and N5 have the potential to be developed as functional foods with dietary fibre content respectively 9.6% and 9.74%, resistant starch content respectively 15.01 mg/100 g and 14.93 mg/100 g. The N3 and N5 formulas have better sensory characteristics than other formulas.

Conflict of interest

The authors declared no conflict of interest.

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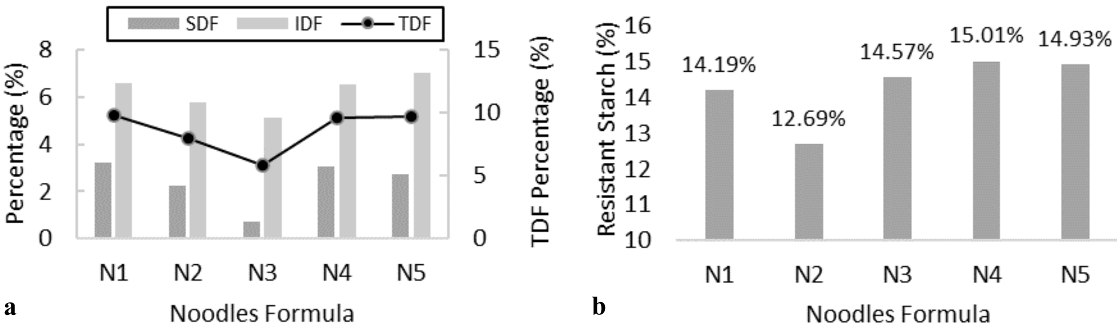

Figure 2. Characteristics of wheat noodles with sorghum and mung beans flour, (a) dietary fiber content and (b) resistant starch content. SDF means soluble dietary fiber and IDF means insoluble dietary fiber.

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